Medical Science

Characteristics of pathological types of breathing in children with community-acquired pneumonia using the "Trembita-Corona" acoustic monitoring device

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ABSTRACT

Introduction: Pneumonia presents a significant challenge in the practical medicine due to its potential to result in severe complications and pose health hazards. *Aims:* To enhance acoustic diagnostics and identify the main pathological types of breathing in children with community-acquired pneumonia using the "Trembita-Corona" acoustic monitoring device. *Methods:* This study adopts a prospective, analytical, and cross-sectional design, involving 330 participants aged between 1 month and 18 years. We categorized them into two groups: Group I comprised 230 patients diagnosed with community-acquired pneumonia (CAP), while group II consisted of 100 healthy children. *Results:* We designed the "Trembita-Corona" device for monitoring lung conditions in children. We employed mathematical algorithms for respiratory sound analysis eliminated human bias. Among children in Group I, we detected bronchial breathing in 213 (92.6%) cases and weakened vesicular breathing in 17 (7.4%) cases. We investigated the pathological bronchial type of breathing using the "Trembita-Corona" device. We found the difference ($p<0.01$) in the amplitude of the acoustic signal between the two types of breathing across various octaves (0, 1, 2, 3, 4, 5, 7, 8). *Conclusion:* The "Trembita-Corona" acoustic monitoring device and its accompanying software enable precise discrimination between pathological and typical breathing patterns in children, thereby facilitating prompt and accurate diagnosis of lung pathologies.

Keywords: Community-acquired pneumonia, acoustic diagnostics, "Trembita-Corona", children.

1. INTRODUCTION

Pneumonia is a significant problem in the field of practical medicine because it can cause severe complications and have potentially dangerous consequences for health (Martin-Loeches et al., 2023; Niederman and Torres, 2022; Marushko and Khomych, 2023). Community-acquired pneumonia (CAP) ranks among the most prevalent pathologies within respiratory diseases. According to the World Health Organization (WHO), more than 1.4 million children under the age of 5 die from pneumonia every year (Marushko and Khomych, 2023; Rothberg, 2022). Modern medical protocols recommend the careful use of diagnostic methods that cause radiation exposure, in particular for mild forms of pneumonia in children. That is why using the X-ray method in the dynamics of treatment is impossible due to the increased radiation load on the patient (Meyer, 2024).

That is why developing new methods of diagnosing pneumonia is an urgent problem, and acoustic methods and new acoustic devices are becoming essential in this context (Chee et al., 2022). Acoustics is a branch of physics that studies sound and its properties. Acoustics is a science that studies mechanical waves that carry sound energy in environments of various natures (Hans et al., 2016; Marushko and Khomych, 2023). One of the critical areas of research is the study of the properties of sound waves and their propagation in air, water, and solids. Acoustic waves are mechanical waves that carry energy through a medium and are transmitted from a sound source, through a specific medium, to a hearing aid. Exploration in the realm of acoustics enhances comprehension of sound's essence and its interaction with nearby entities. These attributes play a crucial role in the advancement of innovative acoustic technologies (Rao et al., 2019).

Acoustics branches into several fields, we focused on highlighting medical acoustics among them. General acoustics delves into the generation and dissemination of sound vibrations, as well as techniques for sound measurement. Architectural acoustics addresses concerns related to noise mitigation. Technical acoustics explores the practical utilization of sound in various technologies. Biological acoustics examines the transmission of sound by organisms. Medical acoustics is dedicated to investigating acoustic phenomena within the medical field (Ahmed et al., 2022; Shahid et al., 2023). In this article, we want to reveal precisely the application of medical acoustics for diagnosing the pathological process in children with CAP. Medical acoustics is a branch that studies sound phenomena in the context of medical research and practice.

This is an important area that deals with the use of sound waves in medicine, as well as the development and application of acoustic technologies in treatment and diagnosis (Singh et al., 2022; Ahmed et al., 2022). The objectives of medical acoustics include establishing hygiene standards for sound usage and innovating diagnostic techniques. In particular, in this study, great importance is attached to the acoustic methods of diagnosing pneumonia in children, the selection of pathological types of breathing, and the development of new acoustic devices for the detection of acoustic signals in frequency ranges that are insensitive to the human ear (Zhang et al., 2021; Marushko and Khomych, 2023). Considering the above, the study aim is to improve acoustic diagnostics and to determine the main pathological types of breathing in children with CAP using the Trembita-Corona acoustic monitoring device.

2. METHODOLOGY

Study Design

Prospective, analytical, and cross-sectional.

Study period

The search was conducted from 1 September 2020 to 31 January 2024.

Study population

The study population consisted of 330 participants, aged from 1 month to 18 years, who were receiving treatment at Children's Clinical Hospitals № 7 and 5 of the city of Kyiv. We divided them into two groups: Group I - 230 patients with CAP, Group II - 100 healthy children.

Setting

We examined the children according to the medical protocols. The patients of group I were diagnosed with CAP according to the evidence-based clinical guideline "Pneumonia in children" (Clinical Guideline 2022-1380 dated 02.08.2022) and the Standards of medical care "Community-acquired pneumonia (CAP) in children" (SMC 2022- 1380, dated August 2, 2022).

Inclusion and exclusion criteria

The criteria for including patients in the 1st group were: children aged from 1 month to 18 years; community-acquired pneumonia confirmed by anamnestic, clinical-laboratory and X-ray data; informed consent of the child's parents or guardians. The criteria for excluding patients from the study were: Chronic bronchopulmonary diseases, cystic fibrosis; congenital and hereditary bronchopulmonary pathology; congenital heart defects; endocrine diseases; refusal to conduct research.

Ethical consideration

The Bogomolets National Medical University Commission on Bioethical Expertise and Ethics of Scientific Research approved the design of this study and informed consent from parents/guardians to conduct the survey (protocol No. 138, 2020). We conducted the study adhering to international principles for clinical research, including GCP and GLP, in line with contemporary bioethical standards and evidence-based medicine practices, following the principles of good clinical practice. The diagnostic measures conducted during this study did not involve any risks.

3. RESULTS

"Trembita-Corona" was created and manufactured specifically for monitoring the condition of the lungs in children and is a patented device. The purpose of the "Trembita-Corona" acoustic lung monitoring device is to detect respiratory sounds and pinpoint the areas of lung abnormalities (Marushko and Khomych, 2023). We analyze respiratory sounds using mathematical methods, excluding human involvement (Marushko and Khomych, 2023). We define the average signal power as the integral of the square of the amplitude over time or frequency, meaning the sum of the squared amplitudes recorded at different points in time. In this case, the integral signifies that the signal is not merely divided into two or three parts, and the averaged amplitudes of each part are not taken. We employed the "Trembita-Corona" acoustic monitoring device and computerized data processing, we segmented the signal into numerous smaller parts and precisely recorded the amplitude value in each segment.

We designated s(t) as a periodic signal with a repetition period of. To According to the European Respiratory Society guidelines (2016) identified types of breathing that are heard as a result of pathology. Pathological types of breathing include: Weakened vesicular, pathological bronchial, bronchovesicular with prolonged exhalation and lack of breathing (Hans et al., 2016). During examination, we detected bronchial breathing in 213 (92.6%) cases and weakened vesicular breathing in 17 (7.4%) cases among children of the first group. There was no detection of bronchovesicular breathing with prolonged exhalation. We investigated the pathological bronchial type of breathing using the "Trembita-Corona" acoustic monitoring device.

We found that the acoustic parameters of physiological bronchial breathing and pathological bronchial breathing differed statistically on 3, 4, 8 and 9 octaves, by the frequency of the acoustic signal on 0, 3, 5 and 8 octaves, and by the amplitude of the acoustic signal on 0, 1, 2, 3, 4, 5 and 7, 8 octaves ($p<0.01$). For example, we want to show the differences between 2 octaves in the acoustic signal amplitude between the physiological bronchial type of breathing and the pathological bronchial type of breathing, presented in Figure 1, to compare the averages of two independent samples, we used the Student's test and the difference was statistically significant ($p=0.004$).

Values of the acoustic signal amplitude for tracheal type of breathing (physiological bronchial) were more significant than for pathological bronchial type of breathing in the corresponding octaves. We analyzed the differences of 5 octaves in the average signal power between the physiological bronchial type of breathing and the pathological bronchial type of breathing presented in (Figure 2). To compare the averages of two independent samples in terms of the average signal power, we used the Student's test, and the difference was statistically significant ($p<0.001$).

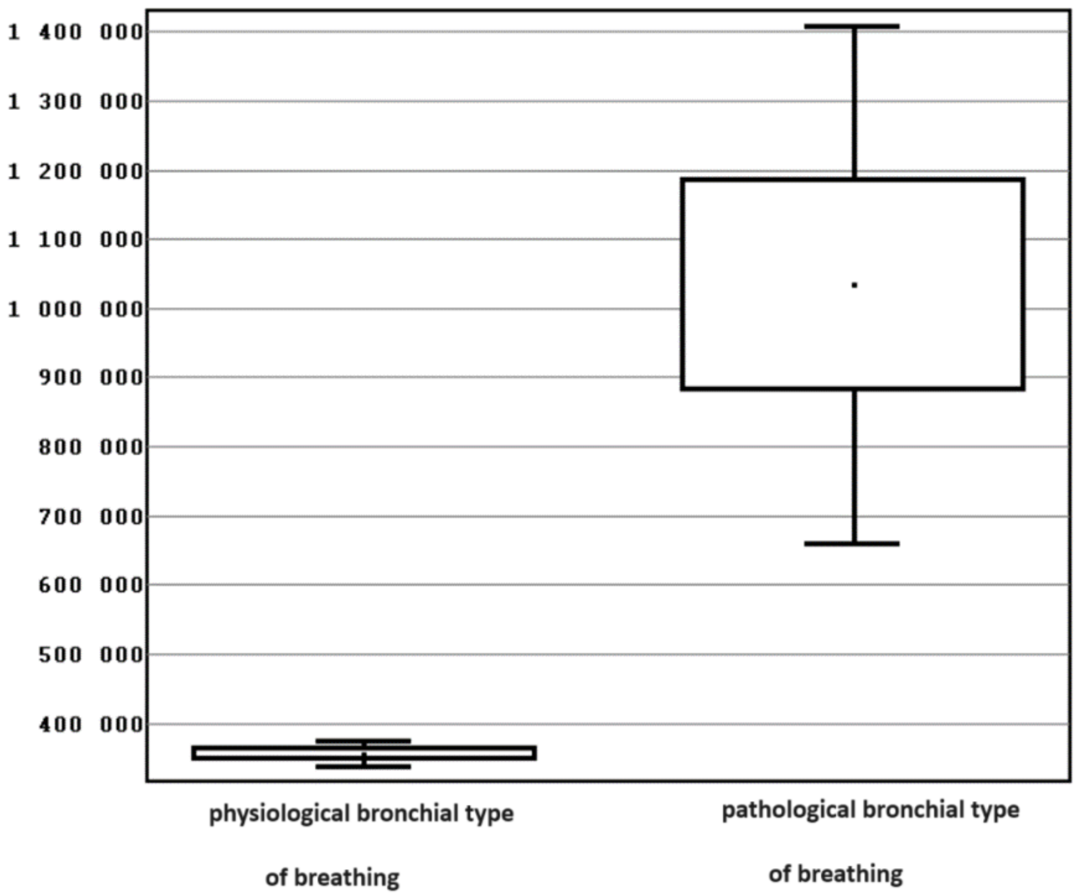

Figure 1 Probable interval of the acoustic signal amplitude when comparing the averages for two independent samples, namely children with physiological and pathological types of breathing.

Also, an essential difference between the two types of breathing is that tracheal breathing (physiological bronchial breathing) is heard only at specific points; this point we denoted by the letter T which is presented in (Figure 3). Pathological bronchial breathing can be heard over any part of the chest.

A weakened vesicular type of breathing was studied using the "Trembita-Corona" acoustic monitoring device. According to the pathogenesis, a weakened vesicular type of breathing occurs due to insufficient air supply to a particular of the lung area. We found differences in the average signal power in 0, 1, 2, 3 and 6, 7, 8 octaves between vesicular breathing (normal breathing) and weakened vesicular type of breathing. Using the "Trembita-Corona" acoustic monitoring device, the main acoustic characteristics of pathological changes in the lungs with CAP were analyzed. We analyzed that the most promising is the determining of the pathological process of lung damage in pneumonia in the ranges from 0 to 8 octaves ($p<0.001$) based on the differences between the average signal strength in children with CAP and healthy children.

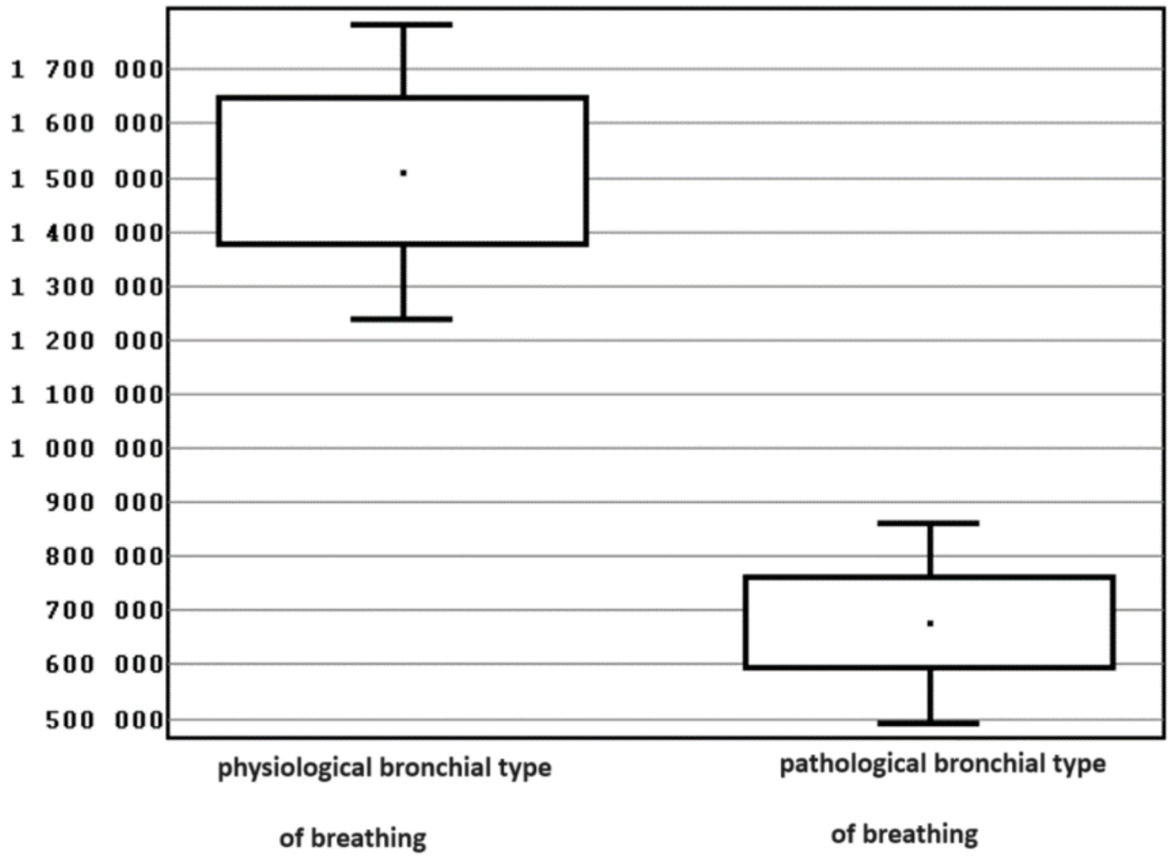

Figure 2 Probable interval of the average signal power when comparing the averages for two independent samples, namely children with physiological and pathological types of breathing.

Figure 3 Point T for auscultation of the lungs with the "Trembita-Corona" device

4. DISCUSSION

We developed and patented acoustic monitoring device with an axial directional pattern "Trembita-Corona" (Patent of Ukraine for utility model No. 148836, 2021). The basis of the invention of the original receiver of the acoustic surveillance device is the task of improving the directionality of the sound-focusing characteristics of the acoustic surveillance device, which has its manifestation in ensuring the possibility of registering an acoustic signal arriving at the antenna parallel to the longitudinal axis of the acoustic antenna and blocking acoustic radiation from other sound sources located from different from the sides of the acoustic antenna, acting on its outer surface of the wall of the acoustic hollow inside the cone of the acoustic antenna, are transmitted to the inner surface of the wall and, composed of vibrations relative to the longitudinal axis that is focused by the cone-shaped acoustic antenna, leads to noise in the acoustic signal, which can critically affect the results of its processing and analysis.

The device has an automated system of control and evaluation of respiratory noises with the complete exclusion of the human factor, and with the possibility of mathematical data processing. To analyze the acoustic characteristics of the recorded signals, select the characteristic frequency ranges and mathematically process the signal parameters, a specialized software was developed with the complete exclusion of the human factor in the Python language in the Google Codelabs environment. We performed further statistical calculations using specialized programs Medstat and EZR (R-Statistics).

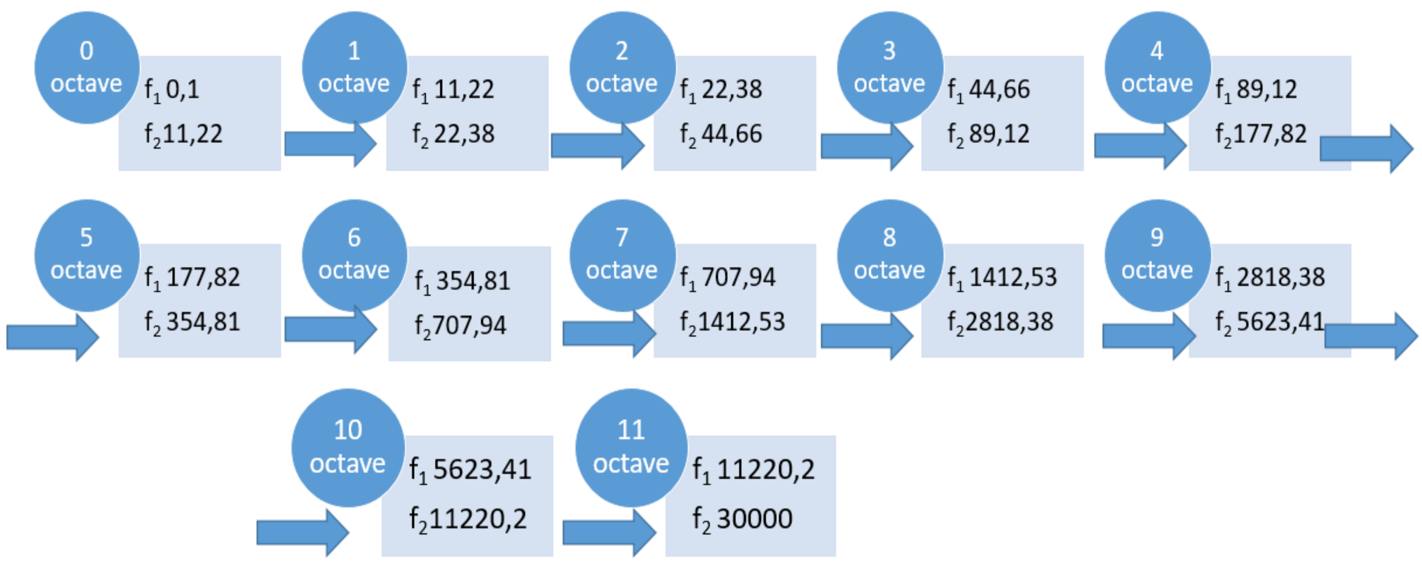

Figure 4 Limit frequencies of the band (f1 and f2) in Hz of the first 11 octaves (f1 and f2 are the extreme frequencies of the band)

The "Trembita-Corona" acoustic monitoring device analyzes sounds across various octave ranges. An octave defines an interval wherein the frequency ratio between sounds is one to two, establishing a stable and fundamental acoustic interval subjectively perceived by the ear in specific octaves (Ahmed et al., 2022; Marushko and Khomych, 2023). Successive octaves consist of sounds similar to each other, albeit differing in pitch. We chose a frequency of 1000 Hz as the baseline frequency. Figure 4 shows the average fm and band-edge frequencies (f1 and f2) (bandedge frequencies) in Hz of the first 11 octaves. The calculations assumed that the lowest and highest octaves encompass frequencies ranging from 0.1 Hz to 30 kHz, respectively.

According to the literature, the human ear can perceive sound signals from 20 Hz to 20 kHz. Infrasound frequencies are in the range below 20 Hz, and ultrasonic frequencies are above 20 kHz, and they are insensitive to human hearing. However, the "Trembita-Corona" acoustic monitoring device works both in the frequency range sensitive to the human ear and in the infra- and ultrasonic ranges that are beyond the limits of perception of the human ear, which is presented in (Figure 5).

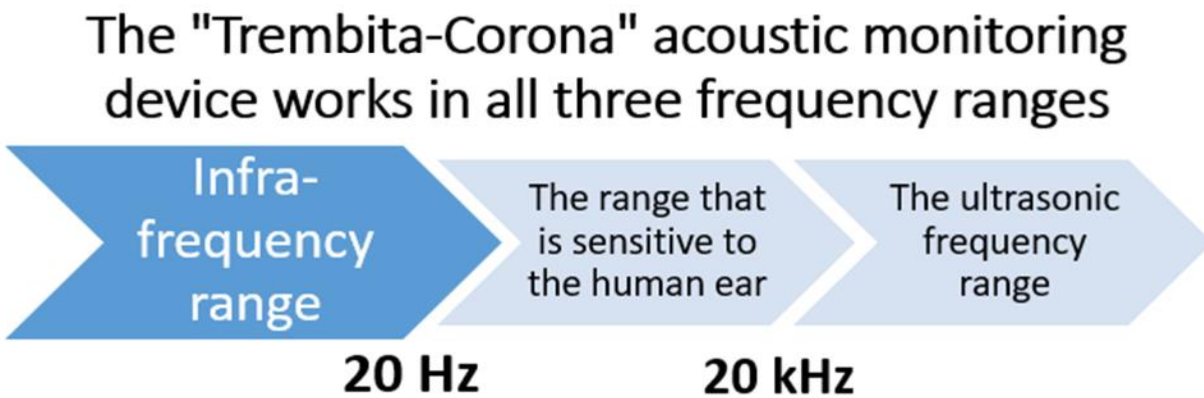

Figure 5 Frequency range of the acoustic monitoring device "Trembita-Corona"

Therefore, the use of the acoustic monitoring device "Trembita-Corona" together with the developed software allows you to accurately detect the differences between pathological types of breathing and types of normal breathing. This makes it possible to speed up the diagnosis of pathological changes in the lungs.

5. CONCLUSION

Utilizing the "Trembita-Corona" acoustic monitoring device in conjunction with the developed software aids in precisely discerning the distinctions between pathological and typical types of breathing in children. This facilitates prompt and efficient diagnosis of lung pathological changes in patients with CAP.

Author Contributions

Olha Khomych: Conceptualization; writing - designing; formal analysis; writing - reviewing and editing.
Oksana Malezhyk: Methodology; writing - reviewing and editing.
Liudmyla Popova: Software; reviewing and editing.
Natalia Kyzyma: Writing - reviewing and editing.
Yuriy Marushko: Review and editing.
All authors analyzed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Medical Ethics Committee of Bioethical Expertise and Ethics of Scientific Research at the National Medical University named after O.O. Bogomolets (protocol No. 138 of November 10, 2020) (Ethical approval code: 138).

Informed consent

Written & Oral informed consent was obtained from all individual participants included in the study. Informed consent of parents/guardians was obtained for conducting the study, which was approved at a meeting of the Commission on Bioethical Expertise at the National Medical University named after O.O. Bogomolets (protocol No. 138 of November 10, 2020).

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Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

REFERENCES

1. Ahmed S, Mitra DK, Nair H, Cunningham S, Khan AM, Islam AA, McLane IM, Chowdhury NH, Begum N, Shahidullah M, Islam MS, Norrie J, Campbell H, Sheikh A, Baqui AH, McCollum ED. Digital auscultation as a novel childhood pneumonia diagnostic tool for community clinics in Sylhet, Bangladesh: protocol for a cross-sectional study. BMJ Open 2022; 12(2):e059630. doi: 10.1136/bmjopen-2021-059630
2. Chee E, Huang K, Haggie S, Britton PN. Systematic review of clinical practice guidelines on the management of community acquired pneumonia in children. Paediatr Respir Rev 2022; 42: 59-68. doi: 10.1016/j.prrv.2022.01.006
3. Hans P, Brand PL, Everard M, Garcia-Marcos L, Melbye H, Priftis KN. Towards the standardisation of lung sound nomenclature. Eur Respir J 2016; 47(3):724-32. doi: 10.1183/13 993003.01132-2015
4. Martin-Loeches I, Torres A, Nagavci B, Aliberti S, Antonelli M, Bassetti M, Bos LD, Chalmers JD, Derde L, De-Waele J, Garnacho-Montero J, Kollef M, Luna CM, Menendez R, Niederman MS, Ponomarev D, Restrepo MI, Rigau D, Schultz MJ, Weiss E, Welte T, Wunderink R. ERS/ESICM/ESCMID/ ALAT guidelines for the management of severe community-acquired pneumonia. Intensive Care Med 2023; 49(6):615-632. doi: 10.1007/s00134-023-07033-8
5. Marushko Y, Khomych O. Characterization of average power, frequency, and amplitude of acoustic signal peaks over the lungs in children with community-acquired pneumonia using the new device "Trembita-Corona". Med Sci Ukraine 2023; 19 (1):53-69. doi: 10.32345/2664-4738.1.2023.08
6. Marushko Y, Khomych O. Sensitivity and specificity of acoustic diagnosis method for pneumonia using Trembita-Corona acoustic monitoring device. Child Health 2023; 18(4):2 62-266. doi: 10.22141/2224-0551.18.4.2023.1597
7. Marushko Y, Khomych OV. Assessment of acoustic signal characteristics in children with community-acquired pneumonia based on the prevalence and nature of lung tissue damage using the new device "Trembita-Corona". Mod Pediatr Ukraine 2023; 2(130):79-88. doi: 10.15574/SP.2023.130. 79
8. Meyer PM. Childhood community-acquired pneumonia. Eur J Pediatr 2024; 183(3):1129-1136. doi: 10.1007/s00431-023-05366-6
9. Niederman MS, Torres A. Severe community-acquired pneumonia. Eur Respir Rev 2022; 31(166):220123. doi: 10.1183 /16000617.0123-2022
10. Rao A, Huynh E, Royston TJ, Kornblith A, Roy S. Acoustic Methods for Pulmonary Diagnosis. IEEE Rev Biomed Eng 2019; 12:221-239. doi: 10.1109/RBME.2018.2874353
11. Rothberg MB. Community-Acquired Pneumonia. Ann Intern Med 2022; 175(4):ITC49-ITC64. doi: 10.7326/AITC202204190
12. Shahid R, Jin J, Hope K, Tunuguntla H, Amdani S. Pediatric Pericarditis: Update. Curr Cardiol Rep 2023; 25(3):157-170. doi: 10.1007/s11886-023-01839-0
13. Singh P, Arshad Z, Srivastava VK, Singh GP, Gangwar RS. Efficacy of Oral Care Protocols in the Prevention of Ventilator-Associated Pneumonia in Mechanically Ventilated Patients. Cureus 2022; 14(4):e23750. doi: 10.7759/cureus.23750
14. Zhang P, Wang B, Liu Y, Fan M, Ji Y, Xu H, Xu M, Chen S, Li Q, Zhang Z. Lung Auscultation of Hospitalized Patients with SARS-CoV-2 Pneumonia via a Wireless Stethoscope. Int J Med Sci 2021; 18(6):1415-1422. doi: 10.7150/ijms.54987